Final Report

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Grantee: Dr. Timothy Duda, Woods Hole Oceanographic Institution
Proposal Title: Scientific Analysis of ASIAEX South China Sea Data
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Abstract: This grant funded follow-up work with data collected under other ONR grants during the 2001 South China Sea portion of the Asian Seas International Acoustics Experiment (ASIAEX). The goals of the effort were to further explain the nature of the fluctuating acoustic signals transmitted from fixed sources to fixed receivers, and to study characteristics of the ambient noise. Both studies are in the band of 200-450 Hz. The received signals from the moored sources have a very complex form, and the long-term goals of our research are to find a robust relationship between characteristic features of the signal fluctuations and features of the internal wave field. Under this grant, various features of the measured acoustic field were examined (some computed under prior grants, and some computed as described below) to prepare for a comparison to the wave field, and a theory was developed for the prediction of the horizontal acoustic coherence scale.

A number of studies were completed under this grant. These will be described below. The results were reported at the Fall 2004 meeting of the Acoustical Society of America in San Diego, CA. A manuscript was prepared for submission to the Journal of the Acoustical Society of America (JASA). The paper is titled "Temporal and cross-range coherence of sound traveling through shallow-water nonlinear internal wave packets" by T. F. Duda. This was not polished into final form before the end of the grant and will be submitted at a later time. The topic of the manuscript is the transverse (normal to the acoustic propagation direction) coherence function of an acoustic field that has been transmitted through a moving packet of internal waves. This situation mimics the acoustic situation and the geometry of the ASIAEX South China Sea (ASCS) field study.

The ASCS experiment was south of the Chinese mainland approximately midway between southern Taiwan and Hong Kong, near the edge of the Chinese continental shelf. The ASCS experiment involved transmission of 224-Hz and 400-Hz pulses 31 km up a slope to an L-shaped horizontal/vertical line array receiver (true heading 340 deg). It also involved 300, 400 and 500-Hz pulses propagated along the continental shelf 21 km at heading 250 deg. The 224-Hz and 400-Hz signals were processed and examined by WHOI under the main ACSC grant and under this grant. The others were processed and studied by the Naval Research Laboratory Acoustics Group Code 7120.

The major accomplishments were (1) the computation of theoretical horizontal coherence functions, which were presented at the meeting and were prepared for submission to JASA (peer reviewed publication); and (2) the computation of vertical beam power curves for the 224-Hz signals, the 400-Hz signals, and noise in various frequency bands between 140 and 700 Hz, which were also presented at the meeting. The beam computations were done by coherently processing receptions on the 16-element vertical line array using a time-delay beamformer.

The coherence function study was motivated by repetition at conferences of a prediction by W. Carey of Boston University that the horizontal coherence length (Yc) of low-frequency sound (a few hundred hertz) on continental shelves is about 30 acoustic wavelengths, and some reports that data supporting this have been obtained. My computations, which are good for sound that is not traveling along internal wave wave crests, covering about 280 of 360 degrees of propagation heading in any given area, give something that I call the "wave packet displacement decorrelation scale" S, from which the coherence scale Yc can be computed for various packet/acoustic relative angles via a formula that I derived. S varies from 5 to 31 wavelengths for frequencies of 100 to 900 Hz. The ratio Yc/S can range from 1 to 40, based on the formula, depending on wave/acoustic relative angle. Thus, in the field, apparent Yc or Yc estimates will vary as a function of time, and the expected value of Yc will be determined by the acoustic propagation direction and the probability distribution of packet angles (and by other packet parameters that can change S).

The vertical beam power results were compared with previous results obtained by OASIS, Inc. for the ONR Southern New England Shelfbreak PRIMER experiment. Temporal mean beam patterns were computed for PRIMER showing appearance and disappearance of a low-angle (near horizontal, low mode) noise notch. The noise notch could last for 10 hours or more during periods of no internal waves, which scatter energy into the notch. Signal behavior from moored sources showed the same result. High temporal resolution computations were done for ASCS, and the noise notch was rarely seen. Presumably, this is because waves are almost always present at the site. Noise and signal behavior showed some correlation. Work in this area will continue under another grant.

During this year, final editorial work was done under the auspices of this grant for three IEEE Journal of Oceanographic Engineering publications, among seven that the PI was author or co-author of:

Duda, T. F., J. F. Lynch, A. E. Newhall, L. Wu and C.-S. Chiu, Fluctuation of 400-Hz sound intensity in the 2001 ASIAEX South China Sea Experiment, *IEEE J. Oceanic Eng.*, **29**, 1264-1279, 2004.

Duda, T. F., J. F. Lynch, J. D. Irish, R. C. Beardsley, S. R. Ramp, C.-S. Chiu, T. Y. Tang and Y. J. Yang, Internal tide and nonlinear internal wave behavior at the continental slope in the northern South China Sea, *IEEE J. Oceanic Eng.*, **29**, 1105-1130, 2004.

Wei, R.-C., C.-F. Chen, A. E. Newhall, J. F. Lynch, T. F. Duda and C.-S. Liu , A preliminary examination of the low-frequency ambient noise field in the South China sea during the 2001 ASIAEX experiment, *IEEE J. Oceanic Eng.*, **29**, 1308-1315, 2004.

The abstract of the ASA meeting presentation appears in JASA:

Duda, T., J. Lynch, P. Abbot, and R.-C. Wei, Vertical line array beamforming of signal and noise in shallow-water regions, *J. Acoust. Soc. Am.*, **116**, 2535, 2004.

Preliminary beamforming results appear in the IEEE Journal of Oceanic Engineering paper with first author Wei.

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14. ABSTRACT

This grant funded follow-up work with data collected under other ONR grants during the 2001 South China Sea portion of the Asian Seas International Acoustics Experiment (ASIAEX). The goals of the effort were to further explain the nature of the fluctuating acoustic signals transmitted from fixed sources to fixed receivers, and to study characteristics of the ambient noise. Both studies are in the band of 200-450 Hz. The received signals from the moored sources have a very complex form, and the long-term goals of our research are to find a robust relationship between characteristic features of the signal fluctuations and features of the internal wave field. Under this grant, various features of the measured acoustic field were examined (some computed under prior grants, and some computed as described below) to prepare for a comparison to the wave field, and a theory was developed for the prediction of the horizontal acoustic coherence scale.

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